WHITE PAPER

canara

# Business Case for Battery Monitoring

*Why condition-based monitoring allows you to predict and preempt issues versus risk and react*

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**INTRODUCTION**

## Overview

In today's data reliant environment, no element can be overlooked in support of total uptime and maximizing your assets. Canara is a full-service solutions provider serving global markets with turnkey battery backup systems and predictive monitoring and maintenance services to ensure against systems' failure. The battery industry veterans who founded Canara realize that multiple vendors and patched together systems put service level agreements at risk and shorten the life of the battery asset investment significantly. That is why Canara created one superior solution for the entire battery lifecycle and united all the critical elements into one seamless package.

Our turnkey solution combines best in class VRLA batteries, easy-to-access cabinets, professional installation in our factory environment or in the field, integration of battery monitoring hardware, remote monitoring, weekly reporting and data analysis, and regular preventive and corrective maintenance to help our customers achieve 100% uptime. Does it work?

While UPS failure is the #1 cause of Data Center outages, Canara customers have never experienced an unexpected battery failure since the Canara Solution provides complete system visibility to predict and preempt UPS & battery failure and avoid the #1 cause of data center outages. Furthermore, Canara customers realize up to 35% extended ROI on their battery investment with our conditions-based predictive monitoring and maintenance program.

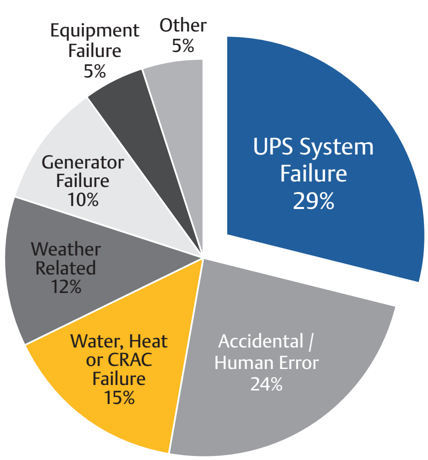


*Figure 1: UPS System Failure is the #1 cause of data center outages*[1]

## Canara's Data Center Customers

Canara's customer base of over 100 organizations is rapidly evolving as the integrated, modular solutions approach is adopted by a range of specifying engineers, end users, market conditions and sensible business models. The core business is compromised of the world's leading data centers and enterprise organizations including Charles Schwab, Cologix, CSC, Digital Realty Trust, Equinix, Fidelity Investments, RagingWire, CenturyLink and ViaWest.

## Battery Failure

One failure in a single battery string can have disastrous and costly consequences from both an impact to negative corporate image to the cost of a customer load loss. Even in a 2N environment – one weak battery in each string can and has caused UPS load loss.

UPS load loss failures are primarily caused by due to weak or failed batteries as they are called upon to carry the load. Furthermore, batteries can fail in as little as a few days making quarterly or semi-annual maintenance visits ineffective.

Sudden Impedance/Resistance Rise (SIRR) in a Stationary Battery is indicated by an exponential rise of internal resistance over a period of a few days to 1-2 weeks. SIRR, which can occur at anytime in the serviceable life of a battery, is a common form of battery failure (from our experience, about 15% of battery failures are due to SIRR). A SIRR battery jar (if not replaced) can cause an open circuit, jeopardizing the integrity and reliability of the entire UPS, DC Plant, Switchgear or Generator Start battery systems. In the worst case, a failed open jar can even explode under load conditions, jeopardizing integrity of surrounding equipment and most importantly – life safety.

The following graph shows a battery failure that happened within a few days as illustrated by the sudden resistance rise and corresponding drop in voltage.


*Figure 2: Battery Failure caused by Sudden Impedance/Resistance Rise*

## CANARA SOLUTION

With the installation of a comprehensive Battery Monitoring System and Canara's patented trending battery management software, battery trends can be predicted in advance thereby eliminating the risk of an SIRR as noted above and subsequent UPS load loss.

**A stepped solution:**

A) Stationary battery monitor data on unit voltage measurements is gathered and then embedded and trended in our monitoring system which detects voltage drop in an individual battery unit which our NOC and site personnel can see clearly from any web browser. In this case, you can see that this happened in a matter of days.

B) Stationary battery monitor data on same unit's Ohmic measurements is gathered and then embedded and trended in our monitoring system which confirms that the battery (or interconnect torque/sulfation) requires conditions based maintenance.

C) Right away, our (or our partners') field technicians are dispatched to verify with a handheld testing unit and visual/physical inspection and replace the unit prior to it compromising the strings ability to carry a load in a discharge event. This is the critical intervention period to perform conditions-based pre-emptive maintenance.

D) The replacement unit is watched carefully to ensure its voltage charge trend is normal and the new battery is integrating with the string properly.

E) The replacement unit is watched carefully to ensure also that its Ohmic trend is within expected range to ensure that the risk exposure has been completely eliminated.

***Note:*** *The above steps are possible with any major brand of battery monitor (Alber, Btech, Cellwatch, Canara), however the Canara monitor also measures and trends the internal temperature of each battery and ripple voltage/current at each battery point to provide much deeper insight into the condition. In this case, two additional trend graphs per battery unit are provided visually to assist onsite personnel and our Canara Insite Center staff in judgment calls on action required.*

## Battery Preventative Maintenance

Following IEEE 1188-2005 it is recommended that, if possible, the following inspections be done under normal float conditions and that measurements and observations should be recorded for future comparisons:

MONTHLY

- Overall float voltage measured at the battery terminals
- Charger output current and voltage
- Ambient temperature
- Visual individual cell/unit condition check to include
  - Cell/unit integrity for evidence of corrosion at terminals, connections racks, or cabinet
  - General appearance and cleanliness of the battery, the battery rack or cabinet, and battery area, including accessibility
  - Cover integrity and check for cracks in cell/unit or leakage of electrolyte
- Excessive jar/cover distortion
- DC float current (per string)

QUARTERLY

- Cell/unit internal Ohmic values
- Temperature of the negative terminal of each cell/unit of the battery
- Voltage of each cell/unit

The reliability of any UPS system can be compromised if this program recommended by IEEE is compromised or omitted.

### CANARA SOLUTION

With the installation of a comprehensive stationary Battery Monitoring System these parameters (minus the visual inspections) are measured four times per day, thus allowing you to reduce your time-based Preventative Maintenance scope to once annually and migrate to a continuous Preventative Maintenance schedule based on actual need.

## Extending Life of the Battery Asset

Without access to comprehensive battery data over the lifecycle of the asset including initial load test results, initial and trended Ohmic values (from multiple daily reads), temperature history, voltage, battery discharge events, depth of discharge, number of individual battery replacements within a string, etc. it is very difficult to determine when to replace an individual battery and more importantly when to replace an entire battery string.

Since this data is not available from quarterly battery maintenance inspections, a standard industry practice has been to perform time-based replacements vs. needs based replacements. The net result of this legacy approach is that many battery strings are replaced pre-maturely and capital costs are not fully realized through amortization over the "true" effective life of the string.

For example, the following table from a recent data center battery replacement project involving 10 UPS modules underscores the value of a "data based" replacement program using empirical data and analysis vs. a time based program.

Using a time-based replacement model of four (4) years would have, in the cases of UPS 1 & 2, exposed the site to a load-loss risk (UPS downtime) with strings lasting only 26 & 22 months respectively, while strings 3 & 4 clearly show the benefit of maximizing the capital cost of the investment out past six years, as in the case of UPS 5 - 9. Note that these batteries are at different locations but for the same customer and the same make and model.

| UPS | Battery Count | Type | Loca-tion | Date Code | Actual Replace-ment Age (Years) | Benefits vs. standard 4-year replacement interval |
|---|---|---|---|---|---|---|
| 1 | 120 | C&D 12-475 | NJ | 11/1/2006 | 2.2 | Avoided risk to connected load |
| 2 | 120 | C&D 12-475 | NJ | 3/1/2007 | 1.8 | Avoided risk to connected load |
| 3 | 120 | C&D 12-475 | NJ | 9/1/2005 | 3.3 | Extended life by 4 months |
| 4 | 120 | C&D 12-475 | NJ | 9/5/2005 | 3.3 | Extended life by 4 months |
| 5 | 120 | C&D 12-475 | LA | 11/15/2003 | 5.2 | Extended life by over 2 years |
| 6 | 120 | C&D 12-475 | LA | 10/15/2003 | 5.3 | Extended life by over 2 years |
| 7 | 120 | C&D 12-475 | LA | 10/15/2003 | 5.3 | Extended life by over 2 years |
| 8 | 120 | C&D 12-475 | LA | 11/15/2003 | 5.2 | Extended life by over 2 years |
| 9 | 120 | C&D 12-475 | LA | 11/15/2003 | 5.2 | Extended life by over 2 years |
| 10 | 120 | C&D 12-475 | LA | 11/1/2004 | 4.2 | Extended life by over 1 year |

*Table 1: Benefits of battery replacement on condition versus time*

### CANARA SOLUTION

Combining a stationary Battery Monitoring System with Canara's predictive analytics and monitoring allows us to collect several key characteristics of a battery string to actually predict the number of years/months of expected remaining service life to each individual string in your infrastructure. This critical asset management function offered by Canara, takes the guesswork out of the equation as strings are replaced upon condition and not time. This method also ensures replacements happen on a planned budget cycle so you can avoid any budget surprises. Our proprietary algorithms for calculating remaining service life include characteristics of temperature history, average ohmic measurement/trend, number of discharges, depth of discharges, battery model/make, UPS Load %, and several other factors.

## The Effect of Ripple Current on Battery Life

One of the growing concerns in the industry today is how excess AC ripple can shorten the service life of batteries. An additional concern is, as UPS capacitors start weakening, they can explode and cause collateral damage to the UPS as well as load loss. One of the major parameters that affect the service life of battery systems is ripple voltage and current.

UPS systems place the highest levels of ripple on batteries due to the noisy nature of the rectification and inversion process of UPS systems. Other system types such as Telecom equipment produce low levels of ripple. However, the presence of excessive ripple, particularly in a Telecom or any 48VDC environment, may be an indication of a system malfunctioning.

In order to understand the nature of ripple generation, a brief tutorial is presented below on the difference between UPS and DC power systems:

## UPS (Uninterruptible Power Systems)

UPS systems provide uninterrupted AC power for computer networks or servers. The UPS rectifier converts the Utility AC voltage to a DC voltage to charge the batteries and also feed the inverter. The inverter feeds an AC electrical load. See Figure 3.

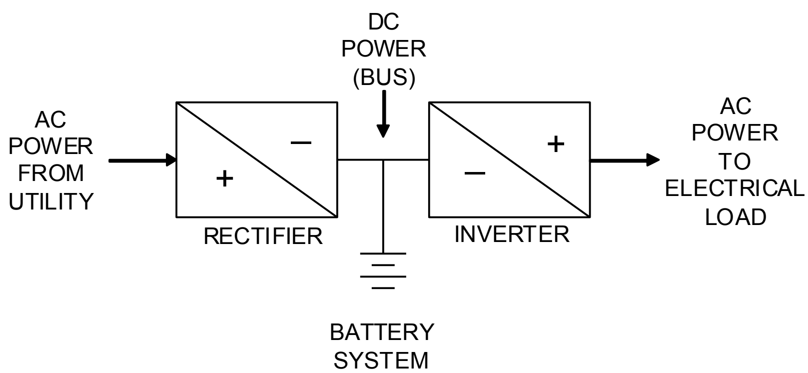


*Figure 3: Typical UPS topology*

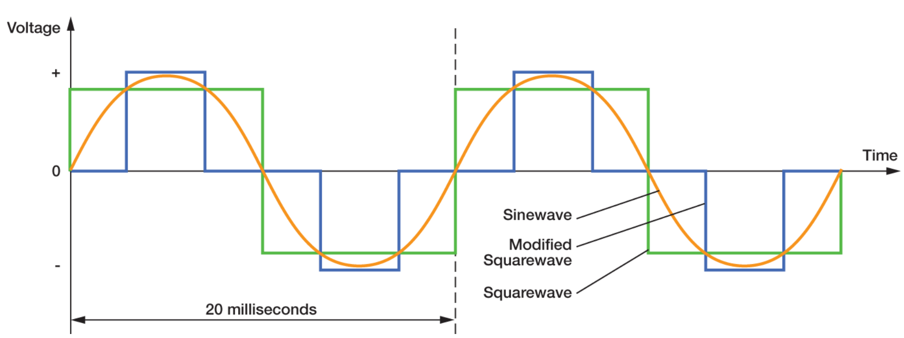


*Figure 4: Inverter Output Sine wave*

Figure 4 illustrates how the output of a UPS system is a regenerated AC sine wave derived from a square wave (filtered). The Insulated Gate Bipolar Transistors (IGBT) turns on and off reproducing the sine wave. AC capacitors smooth out the sine wave.

Figure 5 illustrates where AC ripple occurs as a by product of the rectification process, when converting AC voltage to DC voltage. AC ripple are the filtered remnants of the AC waveform riding over the top of the DC output voltage passing through a DC capacitor network.

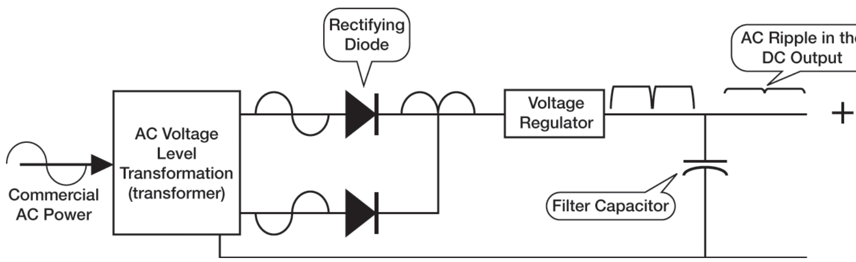


*Figure 5: Rectification of AC voltage producing AC ripple*

The presence of AC ripple voltage leads to shallow discharge cycles producing hydrogen gas, sulfation on the battery plates and heat within the cell due to exothermic electrochemical reactions. As AC ripple voltage increases, AC ripple current rises. An increase of AC ripple current also adds to the internal heat generated inside the battery. Ultimately, excessive ripple current leads to excessive gassing, heat and dry-out, consequently diminishing the service life of the battery.

Excessive AC ripple voltage can also be indicative of failing capacitors that can potentially explode and cause collateral damage to personnel, UPS equipment and UPS load loss.

CANARA SOLUTION

Canara provides the only solution that monitors the ripple so you can successfully prevent harmful levels of ripple voltage and current, from damaging your system's electronics and/or battery system.

## Initial Load Testing

The best way to commission or perform a periodic test of a battery string is to perform an IEEE 1188 compliant load bank test, and gather key data from the battery monitoring system (see Figure 6 below), which performs a rapid scan of each individual battery's voltage. It is important to have a Monitoring Services platform that ensures each battery monitoring system is prepared to correctly detect discharge and enter rapid scan mode to collect this critical data. With this data you can then perform a complete analysis of the resulting data and provide a detailed report of which batteries pass/fail the load testing. This ensures that weak batteries are removed from the string immediately for better warranty claim and longer life string performance.

In addition, this baseline data is used to monitor and predict future trends such as the ohmic rise of each individual battery and the overall trend of the battery string. Each battery is manufactured with a slightly different base ohmic value so using a generic baseline will either lead to batteries being replaced to soon or replaced too late. Further, having accurate baseline data allows you to follow IEEE 1188, which recommends replacing batteries that reach between a 30-50% ohmic rise above their initial baseline.

As illustrated in the chart below, a 10 minute load test performed at 740KW on a 1,000kVA UPS shows battery unit 74 failing the initial load test by ending at 7.71V.

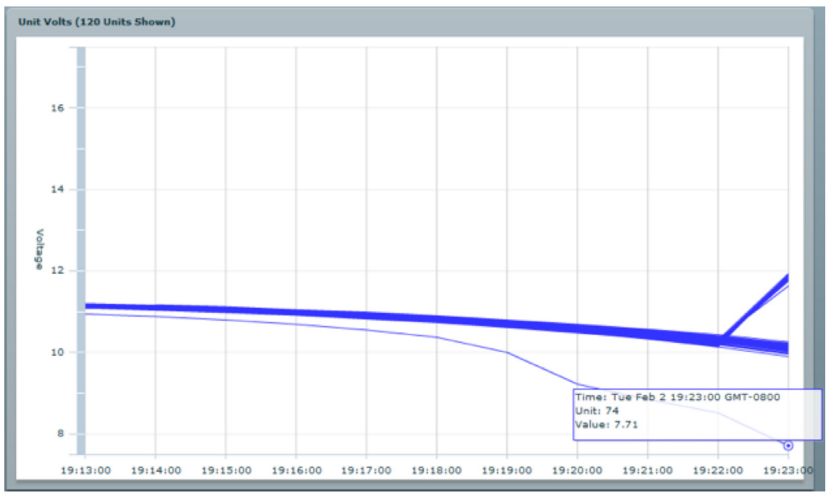


*Figure 6: Load test illustrating battery failure*

### CANARA SOLUTION

The best way to commission or perform a periodic test of a battery string is to perform an IEEE 1188 compliant load bank test, and gather key data from the battery monitoring system, which performs a rapid scan of each individual battery's voltage. This data is then stored and analyzed in our Monitoring Services platform and an IEEE compliant load test report is generated for the customer by Canara Insight Center analysts.

## Return on Investment

The following ROI had been prepared based upon existing customer infrastructure in the U.S. as of 2012 and current operational costs.

## Canara ROI Analysis

| | |
|---|---|
| Number of UPS / Battery systems | 7 |
| Total Number of Strings | 21 |
| Total batteries per String | 40 |
| Total number of batteries to be monitored | 5,880 |
| Battery Cost | $1,764,000 |
| Battery Installation | $176,400 |
| Canara Hardware & Labor | $715,406 |
| TOTAL | $2,655,806 |
| | |
| 12-YEAR COSTS | |
| Non Monitored | $18,778,375 |
| Canara | $14,215,982 |
| Difference | $4,562,393 |
| Avg Savings Year | $380,199 |
| | |
| ASSUMPTIONS | |
| Model is based on 12 years, the estimated life of the UPS | |
| Non-monitored batteries replaced every 4.00 years | |
| Canara batteries replaced every 5.40 years | |
| Number of preventative maintenance visits per year with non-monitored system is 4 | |
| Number of preventative maintenance visits per year with Canara is 1 | |

The ROI is achieved through savings and increased efficiency in the following areas:

- **Reducing Preventative Maintenance Visits:** Maintenance visits can be reduced from 4 to 1 per year since the Battery Monitoring System provides daily visibility into the state of health of each battery and reduces the need for costly and time consuming hand-held testing.
- **Decreased costs associated with battery spot replacements:** With visibility into each battery, spot replacements can be planned in advanced and timed with pre-scheduled PM or service visits. Multiple batteries can be replaced at the same time and work can be planned in advanced so that overtime is not incurred at the site.
- **Extending the battery life:** Capital investment is optimized and batteries are replaced on an as needed basis vs. a time based (e.g. every 4 years) model. On average, battery life can be extended by 6-24 months when predictive analytics and monitoring are deployed.
- **Ensuring Warranty Replacements:** In order to successfully claim a warranty replacement, manufacturers' require batteries to be operated and be maintained within specifications. Since Canara maintains the entire data history for these systems, we are able to certify the battery history against the manufacturers specifications thus ensuring successful replacement.

## Conclusion

Cloud-based monitoring coupled with predictive trending and maintenance is critical to achieving uptime; monitoring hardware alone is not enough. If you are not actively monitoring every day you are at risk of becoming an outage statistic. In fact, most organizations incur significant outage costs with an average cost just over US $740K[1].

If this business case took into account the average outage cost, then the ROI would be less than 3 years.

So if you're interested in:

- Extending battery life
- Reducing costs for maintenance
- Managing assets and accurately forecasting maintenance and string replacements
- Protecting your systems from thermal runaway
- Identifying potential UPS problems
- Knowing about problems before they happen

Then give Canara a call or visit our website to learn how you can get the most out of your battery backup systems.

[1] Ponemon Institute, Cost of Data Center Outages, sponsored by Emerson Network Power, January 2016.

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